§7. Extension of High-Ion-Temperature Regime in LHD

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The production of high-ion-temperature hydrogen plasma was successfully demonstrated in the Large Helical Device (LHD) experiment. The ion temperature (T_i) exceeded 5 keV (the record value of T_i in helical plasmas) at the plasma density (n_e) of 1.2×10^{19}m^{-3} (as shown in Fig. 1) and also achieved 3 keV at n_e~4×10^{19}m^{-3}. This achievement demonstrated the capability of high-ion-temperature plasma confinement in helical devices. The total power of neutral beams as much as 20 MW (3 parallel-injection and 1 perpendicular-injection) and ion cyclotron heating power of about 2 MW contributed to make this realize.

The radial profiles of the toroidal rotation (V_t) as well as T_i were measured by means of the charge exchange recombination spectroscopy (CXRS) with the toroidal-view. The CXRS measurement has clarified that high-T_i plasmas typically have large V_t (as large as several tens of km/s) at the core region accompanied by an increase of T_i gradient. This observation indicates that the ion heat confinement is improved in high-T_i discharges associated with the presence of a large V_t.

It is also interestingly observed that the emission intensity from carbon-impurity ions (for CXRS measurement) at the core region strongly drops as the core-T_i becomes higher. It implies that the carbon-impurity ions are expelled from the core region. This phenomenon has been dubbed as “impurity hole”. This unique feature may provide the efficient knob to avoid the impurity accumulation in reactor-relevant helical plasmas.

We have also initiated the relevant transport analysis. The ions are in $1/\nu$ regime for these high-T_i plasmas, and neoclassical (NC) ambipolar E_r is predicted to be negative (ion-root). This prediction indicates that the hollow impurity profile (usually anticipated from the positive E_r (electron-root)) must be due to effects beyond the NC transport theory. The theoretical study to clarify the role of large V_t for the improved ion heat confinement has also been performed from the viewpoint of plasma viscosity structure in three-dimensional magnetic configurations. It is anticipated that systematic theoretical study may provide fruitful experimental scenarios for pushing the T_i-record higher in LHD.

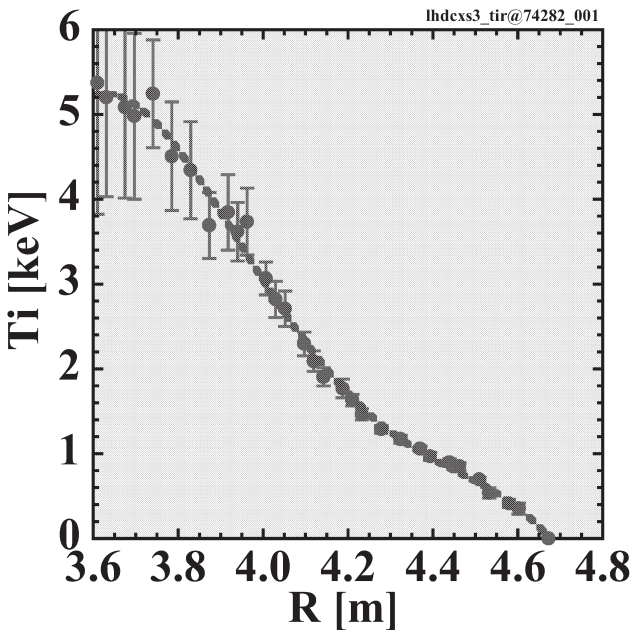

Fig.1 The Ti-profile (measured by CXRS) in the highest-Ti -hydrogen-main plasma (#74282) obtained in the 10th-LHD experimental campaign